

Device for detecting any leak and underinflation in the  
tyres of motor vehicle wheels

5 The invention firstly relates to leakage devices, and  
especially to devices for detecting the puncturing of  
tyres of motor vehicle wheels and more precisely to  
calculating the leakage rate from these tyres.

10 The detection devices may be integrated into computers  
in the passenger compartment or more specifically into  
TPMS (Tyre Pressure Measurement System) modules.

15 A TPMS module collects the information about the  
pressure P and temperature T of the gas contained in a  
tyre by means of sensors and a radio transmitter, these  
generally being fastened to the rim of the wheel. A  
radio receiver placed in the module periodically  
receives a data packet representative of the pressure  
and temperature.

20 The period of collection of the data packets from each  
wheel is, in principle, the inverse of the theoretical  
frequency with which the data packets are transmitted  
by the transmitters, which is determined by the  
25 passenger compartment computer according to the  
operating state of the vehicle (at rest or running).

30 To detect a leak, its leakage rate may be calculated  
from the change in the pressure, from one data packet  
to another, at the above theoretical frequency, that is  
to say the leakage rate is calculated from the pressure  
difference recorded over the theoretical time.

35 However, this detection is not ideal.

Firstly, the temperature of the rim, and therefore of  
the gas contained in the tyre, may vary substantially,  
for example during a braking operation. This causes a  
change in the pressure and a change in the calculated

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leakage rate that may be interpreted wrongly as a leak. This is because the thermal compensation, even if it is applied, has no immediate effect given the long response time of a temperature sensor, which is longer  
5 than that of a pressure sensor.

Secondly, the time between two data packets may not be constant:

1) it may be intentionally reduced, for example if  
10 the tyre pressure monitoring requires to be increased, in which case the calculated leakage rate decreases with time between two data packets;

2) it may unintentionally increase in the event of a data packet being lost, caused by a poor radio link.  
15 The calculated leakage rate may then double, triple, etc., unbeknown to the TPM module, which therefore cannot apply the slightest correction.

Mathematical algorithms for smoothing temperature and  
20 pressure data in order to attenuate the effects of these sources of error are known. However, this solution does not prevent a delay in detecting an actual puncture, or an adventitious detection. This may be prejudicial to the safety of the driver and the  
25 passengers of the vehicle.

The Applicant was set this problem and, to solve it, proposes a device for detecting a leak in a tyre of a motor vehicle wheel, comprising means for measuring the  
30 pressure of the gas contained in the tyre, means for collecting pressure measurement data and means for calculating the change in pressure between two instants of measurement data collection, which device is characterized in that it includes means for clocking  
35 the time of the measurement data collection and for calculating the change in pressure between clocked instants of collection.

Scorning cheap solutions, the Applicant therefore dared

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to introduce additional means in the aim of increasing safety, using a solution which *a priori* is more logical but which had been discarded.

5 The means for clocking the measurement data collection allow the air leakage rate to be calculated more precisely, whatever the frequency of measurement data collection and whatever the conditions of data packet radio transmission.

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Preferably, the calculating means are designed to calculate a thermally compensated change in pressure.

15 The invention will be more clearly understood from the following description of one embodiment of the device of the invention and from the single appended figure that shows a functional block diagram of the device.

20 A device 1, for detecting a leak and more commonly a puncture, of a tyre 2 of a wheel 3 of a motor vehicle (not shown), periodically receives, via a radio link 10, data packets, including the instantaneous pressure P of the gas contained in the tyre and possibly its temperature T. The quantities P and T are measured by  
25 sensors (not shown) in a module 4 fastened to the rim or to the valve of the wheel 3, on the inside of the tyre 2. It is the module 4, also equipped with a transmitter (not shown), which transmits the abovementioned data packets.

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The detection device 1 comprises means for collecting the measurement data packets from the module 4, a receiver 5 for receiving the radio signals 10 and converting them into analogue electrical signals, and a  
35 demodulator 6 that converts these analogue signals into digital signals and then into digital data, including the pressure P and the temperature T of the gas in the tyre.

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The device 1 also includes, on the output side of the demodulator 6, calculating means 7, here a microprocessor, for calculating the rate of any leakage from the transmitted data P and T. The calculation of  
5 the leakage rate is performed by a module 71, calculation being initiated each time a data pair (P, T) is available at the output of the demodulator 6. A module 72 for detecting a change in pressure delivers  
10 puncture or leakage detection information to the user, via the output 11, on the basis of the information delivered by the module 72 and a module 73, on the output side of a module 8, for calculating the time difference between two successive data pairs. The  
15 module 8 is a clocking module, which comprises a clock 81 and a memory 82, for clocking the time at which the measurement data is received, this being controlled by the receiver 5 by means of an interrupt system 9. The  
modules 73 and 8 here are integrated into the microprocessor 7.

20

The operation of the detection device will now be described.

When the receiver 5 receives a data packet  $\Theta_i$   
25 containing the data  $P_i$  and  $T_i$ , it transmits an interrupt signal 9 controlling the clocking module 8. This records, in the memory 82, the instant  $t_i$  of the clock 81 corresponding to receipt of the data packet. It then transmits the data packet  $\Theta_i$  to the demodulator 6, which  
30 extracts the data  $(T_i, P_i)$  therefrom and transmits the data to the microprocessor 7. The microprocessor 7, upon receipt of the data pair  $(T_i, P_i)$ , reads the instant  $t_i$  available in the memory 82, already present thanks to the interrupt system 9.

35

On receiving the next data packet  $\Theta_{i+1}$ , the microprocessor likewise obtains  $(T_{i+1}, P_{i+1})$  and  $t_{i+1}$ .

The difference calculation module 73 calculates:

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$$\Delta t = t_{i+1} - t_i.$$

The leakage rate calculation module 71 calculates:

$$\Delta P = P_{i+1} - P_i.$$

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The detection module 72 then calculates the leakage rate via the formula giving the change in pressure:

$$D_p = \Delta P / \Delta t$$

- 10 and compares  $D_p$  with a puncture or leakage detection threshold  $S_p$  above which an alarm is transmitted on the output 11 of the microprocessor 7.

15 However, the expression  $\Delta P / \Delta t$  is, as it were, a rate of change of pressure, whereas what it is desired to obtain is a change in the amount of gas. However, a tyre is not isothermal - it is perfectly possible for there to be a change in pressure without there being a change in the amount of gas. Now, it is just as  
20 important to detect a leak when it occurs as to not detect it when it does not. It is under such conditions that the Applicant has considered it to be preferable to integrate the temperature into the calculations proposed for alleviating the abovementioned situation.

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In the equation:

$$PV = nRT \quad (1)$$

taken into account in the above calculations with, as assumptions, that the inside of the tyre contains a  
30 perfect gas mixture and that its internal volume is constant,  $R$  is the perfect gas constant and  $n$ , representing the number of moles, is also constant if there is no leak.

- 35 A detection threshold is supplied by the tyre manufacturer or the vehicle manufacturer. However, such a threshold is supplied for a reference temperature  $T_{ref}$ .

If it is therefore desired to take this into account, the measured pressure has to be compensated by the temperature and it is necessary to consider, not the measured pressure  $P_m$ , but the compensated pressure  $P_c$ , which is related to  $P_m$  through Equation (1) and, from the assumptions associated therewith, through Equation (2):

$$\frac{P_m}{T_m} = \frac{P_c}{T_{ref}} \quad (2)$$

in which  $T_m$  is the temperature measured inside the tyre at the same time as  $P_m$ .

This results in Equation (3):

$$P_c = P_m \frac{T_{ref}}{T_m} \quad (3)$$

It is on the basis of the value of  $P_c$  that it will be decided, if this is the case, that a threshold has been exceeded and that an alarm has to be transmitted.

However, in Equation (1), the pressure  $P$  is an absolute pressure, expressed in pascals or in bar, and likewise  $T$  is an absolute temperature, expressed in kelvin.

When the pressure of a tyre is measured, both by the module 4 and at a service station, it is a relative pressure that is measured. When 0 bar is measured, the absolute pressure is in fact 1.014 bar.

Thus, if the measurement temperature is for example 20°C, Equation (3) has to be corrected in order to become Equation (4):

$$P_c = (P_m + 1.014) \frac{T_{ref}}{T_m} - 1.014 \quad (4)$$

in which  $P_c$  and  $P_m$  are relative pressures, the temperatures  $T_{ref}$  and  $T_m$  being expressed in kelvin.

Of course, apart from detecting a leak, the considerations developed above also apply just as well

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to detecting any underinflation of a tyre, Equation (4) being able to be used to compare the compensated pressure with a plurality of underinflation thresholds. It should be noted that a puncture may be likened to an  
5 underinflation.

Under these conditions, the calculating means (7) are of course designed to implement the equations presented above.

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An alarm may also be provided, which emits a signal controlled by the compensated pressure, whether a leak is detected or whether underinflation is detected.